# Sloan Digital Sky Survey and Hubble Ultra Deep Field Data Imply a New Cosmological Model

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New empirical data from over 756,000 galaxies in the Sloan Digital Sky Survey and corroborating data in the literature from 1308 galaxies in the Hubble Ultra Deep Field are inconsistent with basic Big Bang theory predictions. These robust high-quality datasets instead confirm the predictions of a simpler cosmological model having no free parameters to adjust the model's predictions of empirical observables. This new model predicts multiple distinct empirical observations with unprecedented precision, rests on established first principles and does not interpret astrophysical observables as accelerating cosmic expansion. It is primarily based on a synthesis of Riemannian geometry and insights concerning the geometric nature of relativistic time arising from fundamental contributions to the relativity theory made by Einstein's university mathematics professor, Hermann Minkowski (1864–1909).

In the late 20th century, measurements were being conducted to determine the value of the cosmic deceleration parameter ($q$). Deceleration was expected because gravity is an exclusively attractive force: it was believed that mutual gravitational attraction of all galaxies should cause the expansion of the Universe precipitated by the Big Bang to gradually and increasingly slow down over time, similar to the slowing of any mass ejected vertically from the Earth's surface. In 1998 it was announced that, instead of the expected deceleration, astronomical observations implied the existence of an accelerating cosmic expansion (*1,2*). Because this notion is inconsistent with the foundations of physics, a scientific crisis ensued and the ill-defined term 'dark energy' was coined to give a name to the unknown agent causing the apparent acceleration of cosmic expansion. Sawangwit and Shanks have recently challenged the validity of key empirical data in support of both 'dark energy' and 'dark matter' (*3*,*4*). Robust new empirical evidence presented herein confirms major inaccuracies in previously reported empirical data that led to the cosmic acceleration interpretation and the ensuing scientific crisis. This new data, additional astrophysical data and a new theory accurately predicting all of the main cosmological observables are discussed at length in a pending dissertation, for which a June 2010 open access preview edition is currently available (*5*). These observables and explanatory new theory imply an unexpected and unprecedented complete revision of the standard cosmological model. Prior to proceeding with the following main article, readers who are inexpert in the fundamentals of conventional modern cosmology are encouraged to read a brief supplementary review of the subject, which is available online (*6*).

**2dF observations support the Big Bang theory.** The Two Degree Field (2dF) Galaxy Redshift Survey of about 250,000 galaxies in the southern sky (*7*), which was a British-Australian effort completed in 2003, represented the largest available cosmological dataset until more recent progress of the American Sloan Digital Sky Survey (SDSS),

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which has mapped and analyzed over one million galaxies and quasars in the northern sky (*8*). The tiny blue dots in Fig. 1 are reported measurements of the redshift ($z$) and apparent magnitude in violet to green visible light ($m_{Bj}$) for 220,661 individual galaxies identified as having accurate high-quality redshift measurements. The dataset is so large that most of the dots appear as a solid blue mass in the graph. Given the apparent assumption that the brightest galaxies (i.e., the base of the dataset, which appears here as the right edge) represent a standard candle, the 2dF data shown in Fig. 1 seems to provide strong confirmation of the 'Hubble law' underlying the standard cosmological model. However, the noticeable absence of relativistic time dilation dimming (*9*) in this data immediately suggests that something is wrong (see Fig. 1 legend).

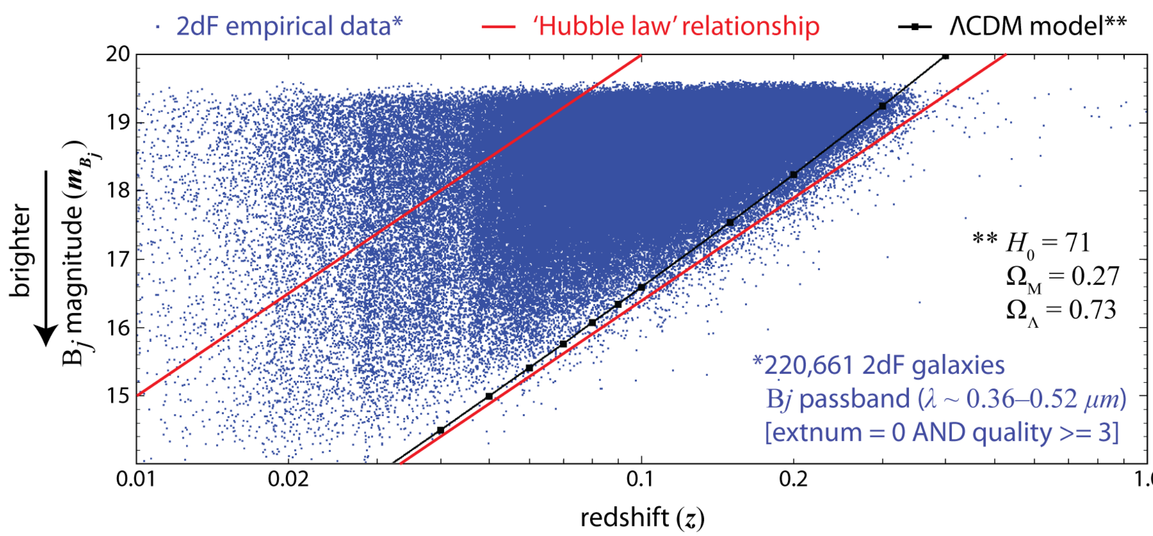


**Fig. 1.** The redshift-magnitude diagram from the 2dF galaxy redshift survey database. This graph's boundaries truncate 5.4% of the complete 2dF database population of 233,251 galaxies for the selection clause (extnum = 0 and quality ≥ 3), which returns data with high-quality *redshift* measurements. The survey employed a B*j* bandpass filter, which primarily includes blue light, although this wide band ($0.36 < \lambda < 0.52\ \mu m$) extends from violet to green. The plotted coordinates are the *z_helio* and *BJSEL* columns of the online 2dF database. The parallel red lines show an increase of exactly five magnitudes (÷100) in apparent luminosity for a ten-fold increase in redshift. Strangely, this data is a better fit to a naïvely simplistic relationship accounting only for the luminosity inverse square law in a Euclidean space than a more sophisticated model that of necessity accounts for relativistic effects, such as the Lambda-cold dark matter 'Concordance' model curve in black (*10*). Empirically, dimming of a standard candle due to distance is accompanied by relativistic time dilation dimming: at $z = 0.04$, time dilation dims a standard candle by $0.09\ mag$ and at $z = 0.4$, by $0.73\ mag$, thus an empirical standard candle cannot possibly follow a strict 'Hubble law' redshift-magnitude relationship.

**SDSS observations refute the Big Bang theory.** The Sloan Digital Sky Survey (SDSS) has been the most ambitious and complete galaxy redshift survey to date. The tiny red dots in Fig. 2 are reported measurements of the redshift and SDSS $i'$-band apparent magnitude ($m_{i'}$) for 756,851 individual galaxies identified as having accurate high-quality

redshifts per these limited values [3, 4, 6, 7, 9] of the SpecObj.zStatus SDSS SkyServer database column (*11*). The $i'$-band "fiber magnitude" specifying the measured brightness of galaxies is the flux contained within the aperture of a spectroscopic fiber with a diameter of three arcseconds on the sky (*12*). Quasars are excluded, so the plotted galaxies are all of the same spectral class. The survey is magnitude limited; galaxies brighter than $m_{i'} = 14.5$ were excluded from measurements to prevent saturation and cross-talk in the spectrographs (*13*). The average error in the magnitude measurement is less than 0.01 *mag*, which is smaller than the dot size on the graph. The typical error in the redshift measurement is similarly small on the redshift scale of the graph. This dataset was acquired without a theoretical agenda; instead, the practical agenda was to ensure individual measurement quality, yielding a collective "cosmic map" providing an unadulterated factual cosmological perspective. (See "Supporting Online Material" after references for detailed instructions to reproduce all of the graphs presented in this article.)

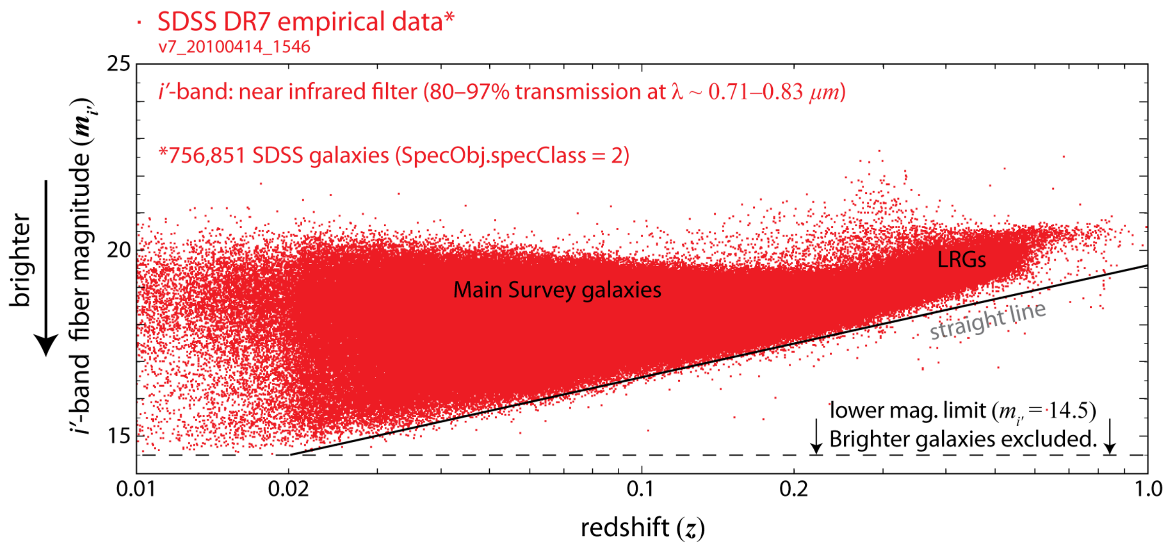


**Fig. 2.** Over 756k high-quality SDSS $i'$-band redshift-magnitude measurements restricted to the galaxy spectral class appear in red. The solid black straight line is approximately tangent to the base of the dataset. With the relatively rare exception of unusually bright outliers, galaxies brighter than the neighborhood of this line do not exist. Like the 2dF dataset, the base of this dataset represents the *brightest galaxy* class, assumed to represent a standard candle because it is not sensible for a large systematic change in their absolute luminosity to exist as a function of redshift. However, the slope of the base of the SDSS dataset is unexpectedly very different from that of the 2dF dataset, which requires explanation. Additionally, a definite increase in the slope of the base of the SDSS dataset is seen for ($z > 0.2$), which is qualitatively similar to that seen in SNe Ia redshift-magnitude data (*14*). The faint galaxy (i.e., top surface of the dataset) population surge at high-redshift is an artifact of the Luminous Red Galaxy (LRG) Survey (*15*), which is incorporated with the Main Survey.

The SDSS data shown is most remarkable in that it does not support the 'Hubble law,' which is made plainly evident in Fig. 3. The solid curve in blue represents the standard cosmological model. No straightforward mathematical formula exists to plot this curve;

even with maximum simplification, a software program taking into account these four parameters ($z$, $H_0$, $\Omega_M$, $\Omega_\Lambda$) is required (*10*). The increase of 5.3 *mag* over ($0.02 \leq z \leq 0.2$) is a reflection of the 'Hubble law' and the luminosity inverse square law. At what is modeled to be a factor of ten increase in distance ($D$) for the same in redshift, the modeled apparent luminosity ($L \propto D^{-2}$) has decreased by a factor of 100, with the excess 0.3 *mag* attributed primarily to relativistic time dilation dimming [$(z + 1)^{-2}$]. Large-scale cosmic geometry (i.e., "spacetime curvature") causes an additional decrease in the apparent luminosity of galaxies at cosmological distance. Although the solid blue curve in Fig. 3 represents the Concordance cosmology, variation of assumed free parameters such as *lambda*, which is related to the alleged acceleration, cannot alter the fit of the curve to the 'Hubble law,' particularly over this redshift range. The dashed blue curve shifts the solid line down about 3.1 magnitudes (×17.4) at $z = 1$, correlating the prediction with the high-redshift empirical data at $z = 0.6$, rather than the low-redshift $z = 0.02$ data. If the 'Hubble law' holds, no galaxies should exist that appear brighter than (i.e., below) the solid blue line, but hundreds of thousands do; alternatively, there is an empirical deficit of galaxies (blank area) that appear fainter than (i.e., above) the dashed blue line.

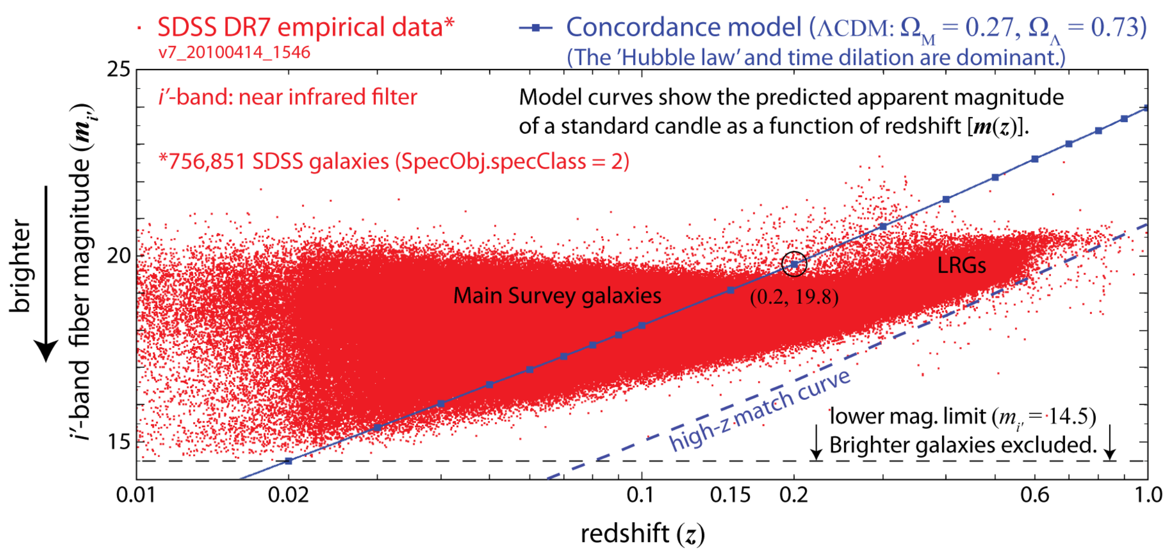


**Fig. 3.** SDSS $i'$-band data compared to ΛCDM Concordance model curves. Given the understanding that the base of the $z > 0.02$ dataset represents a standard candle, the empirical data does not support the 'Hubble law.' The existence of a vast number of galaxies below the solid blue curve implies that this curve is not an accurate redshift-magnitude model. The dashed curve in blue shifts the solid curve down 3.1 *mag* at $z = 1$ to match the high-redshift empirical data. The massive deficit of galaxies (blank area) between the dashed blue curve and the empirical data ($z < 0.6$, $m_{i'} > 14.5$) implies that this "high-*z* match curve" is not an accurate redshift-magnitude model.

Because the Hubble law provides the foundation of the standard cosmological model, one might assume that the SDSS team unknowingly incorporated a huge systematic error in their measurements of galaxy luminosity. Error bars in the magnitude measurements are on the order of 0.01 *mag*, but deviation between theory and empirical data in Fig. 3

grows to ~3 *mag* or ~300× the reported measurement error. It is difficult to believe that such an enormous systematic error could exist, let alone go unnoticed by every member of a large world-class team of scientists and technicians. An alternative possibility is that the SDSS redshift-magnitude data is empirically accurate but was never presented for critical analysis as shown in Fig. 3. Thus, the scientific implication of this data that was 'hiding' in the database was simply overlooked. Trusting that the empirical data produced by the SDSS consortium is accurate as claimed puts the standard cosmological model and the general theory of relativity upon which that model is based in jeopardy.

**The geometry of time in relativity and cosmology.** In 1908, Hermann Minkowski provided a formal mathematical foundation for the special theory of relativity. In addition to unifying space and time, Minkowski had geometrized time, yet Albert Einstein, who initially dismissed this mathematics as "superfluous erudition" (*16*), subsequently never developed an adequate understanding of Minkowski's critical contribution to relativity. Minkowski died suddenly in January 1909 at the age of 44, so his work in progress was never finished. Because Einstein, his contemporaries and several following generations of theoretical physicists never properly understood *the geometry of time* implied by Minkowski, general relativity and the standard cosmological model, which is based on this theory, were both flawed and remained uncorrected in the twentieth century (*5*).

The following parsimonious mathematical equation predicts the apparent magnitude of a cosmological standard candle as a function of redshift. It is based on the idea that the relativistic cosmological *geometry of time* implied by the principles of relativity results in a redshift-distance relationship that is independent of any relative motion. This equation, expressed in the simplest form of Pogson's equation (*17*), which defines the astronomical magnitude scale, rests on pure Riemannian geometry and on fundamental laws of physics that have been empirically verified in the laboratory. It has no free parameters that may allow the prediction to be manipulated *a posteriori* to improve its fit to observations.

$$m(z) = C - 2.512\log\left(\frac{1}{4\pi\left[(z+1)^4-(z+1)^2\right]}\right) \qquad [z>0] \tag{1}$$

The "MdR" cosmological model, which spawned this equation, is based on a synthesis of original ideas put forward by Hermann **M**inkowski (1864–1909), Willem **d**e Sitter (1872–1934) and Bernhard **R**iemann (1826–1866). The fractional term in Eq. 1, which represents a normalized luminosity, incorporates a product of three distinct terms:

(**a**) a geometric term associated with a spatially finite yet boundaryless symmetric spacetime (i.e., a Riemannian hypersphere with a finite volumetric 'surface area' whose local vertical represents the strictly local cosmologically relativistic time coordinate);

$$\frac{1}{4\pi\left(1-\frac{1}{(z+1)^2}\right)} \qquad [z>0] \tag{2}$$

(**b**) the familiar term in astrophysics associated with relativistic time dilation dimming of a radiation source: $(z + 1)^{-2}$;

(**c**) a second relativistic term associated with the effect of cosmic geometric symmetry enforced by gravity (i.e., "spacetime curvature") on the apparent luminosity of a standard candle with redshift. Previously unknown, the value of this term is also $(z + 1)^{-2}$.

The constant 2.512 is the fifth root of 100 (i.e., Pogson's ratio), which is the base of the astronomical magnitude scale. The arbitrary constant $C$ is determined for a class of standard candle (e.g., brightest conventional galaxies) and bandpass filter (e.g., Fig. S1) according to an observed reliable empirical relationship ($z_0$, $m_0$). This equation is among several similar *a priori* exact theoretical predictions of cosmological observables in the MdR theoretical model that rest exclusively on first principles and four-dimensional Riemannian geometry (*5*). There are no free parameters involved in any MdR prediction.

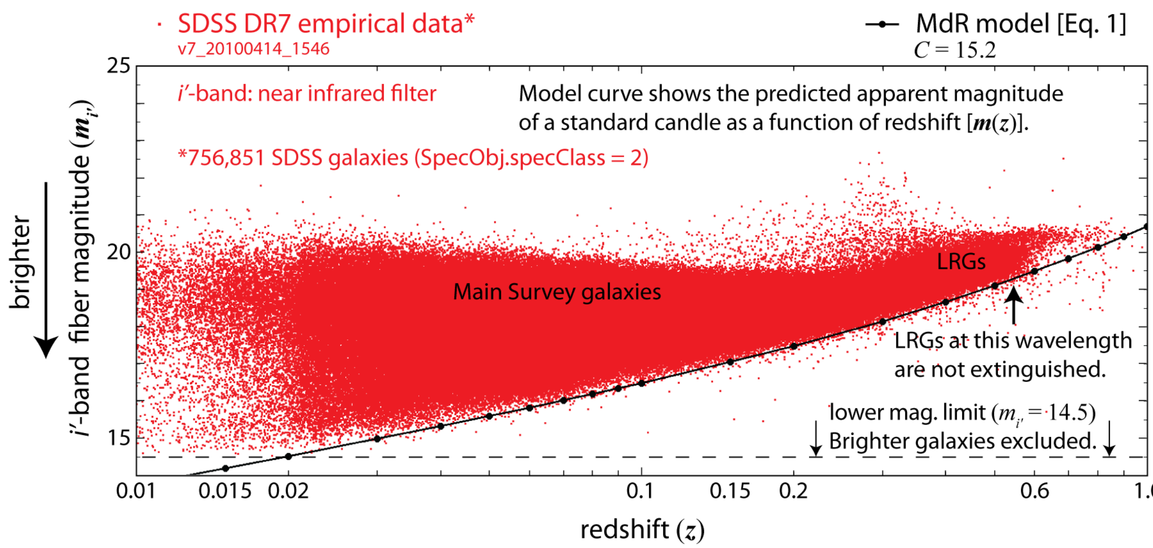


**Fig. 4.** SDSS *i*′-band data compared to MdR model curve. This MdR model assumes a standard candle in an ideal vacuum. In reality, an intergalactic medium (IGM dust) exists; longer wavelength (i.e., redshifted) infrared (IR) radiation penetrates this dust better than shorter wavelengths. Accounting for geometric and relativistic effects, a more distant redshifted standard candle viewed at longer IR wavelengths that better penetrate dust will appear to be brighter relative to a closer standard candle viewed at shorter IR wavelengths, which are "extinguished" (i.e., dimmed) by IGM dust. Accordingly, the small gap between the MdR curve and the empirical data at $z = 0.02$, which narrows over the redshift range ($0.02 \leq z \leq 0.6$), shows about 0.25 magnitude (~26%) relative brightening of the empirical data over this range. (If the gap were removed by shifting the model up ~0.25 *mag*, the high-redshift data would fall below the model curve indicating that the longer wavelength light is relatively brighter than the shorter wavelengths. This effect is more prominent in the *z*′-band (infrared) data shown in Fig. S2.

In Fig. 4, the empirical redshift-magnitude curve for brightest conventional galaxies (excluding outliers) is very accurately predicted by invoking only relativistic effects and cosmic geometric symmetry as modeled by Eq. 1 (solid black curve). This is additional

evidence to Fig. 3 that the 'Hubble law' is indeed false. Eq. 1, which rests *a priori* on first principles and geometry, provides an essentially perfect fit to the SDSS empirical data; that this could be so without physical cause or meaning is implausible. Comparing the two competing models to the empirical data in Fig. 3 and Fig. 4, it is absolutely clear which model's predictive curve fits the empirical data and which model's predictive curve does not correlate with the data. Moreover, the SDSS data is so good that one can see the effect of the intergalactic medium, which scatters and extinguishes light with a wavelength apparently smaller than the average-sized IGM dust grains while allowing longer wavelength light to pass more freely (see Fig. 4 legend and Fig. 5).

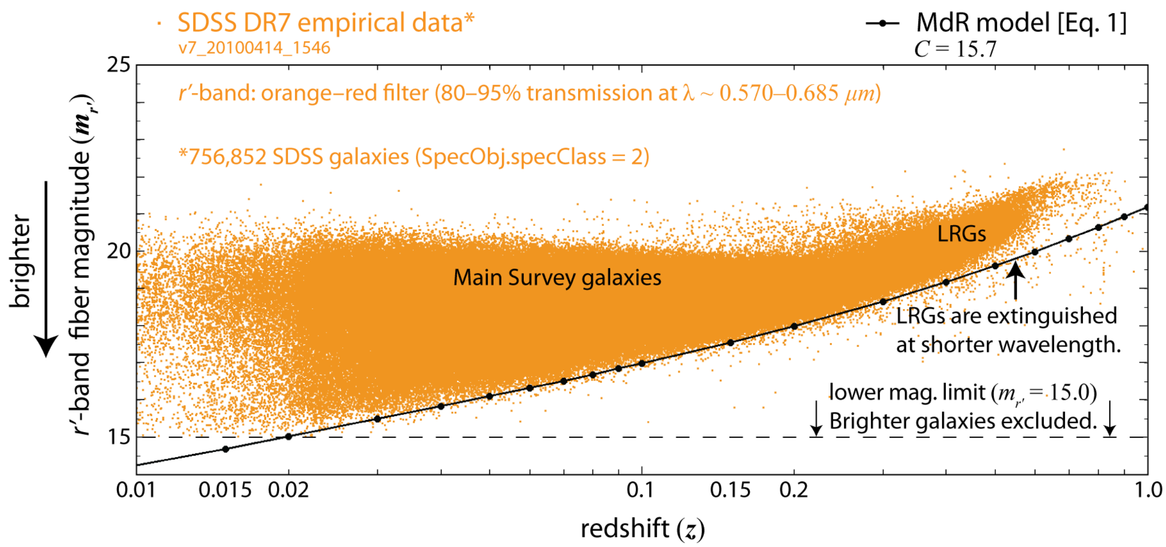


**Fig. 5.** SDSS $r'$-band (orange-red light) data compared to MdR model curve. This filter's light is too short to avoid scattering (i.e., "extinction") by dust. The observed dimming of the $z > 0.4$ $r'$-band data relative to the MdR model curve, which differs from the behavior seen in the $i'$-band data (no dimming) shows that the Luminous Red Galaxies (LRGs) are locally surrounded by dust, which blocks shorter wavelengths. This extinction effect is amplified for shorter wavelengths as seen for blue–green light in Fig. S3. Note that the arbitrary constant in Eq. 1 for the $r'$-band data curve requires an increase from its $i'$-band value by 0.5 *mag* to $C = 15.7$, matching the increase in the SDSS fiber magnitude cut at this shorter wavelength (horizontal dashed line).

However compelling the match of the SDSS empirical dataset to the Eq. 1 theoretical prediction, a skeptic may claim that since this dataset terminates well before $z = 1$, a demonstration of predictive accuracy at high redshift is required for a comprehensive vetting of the MdR model as concerns the empirical redshift-magnitude relationship. Thus we turn to the Hubble Ultra Deep Field (HUDF) image (*18*), which includes 1,308 conventional galaxies, many at very high redshift, whose fundamental properties have been measured from the data with good reported accuracy by R. E. Ryan *et al.*, also using an $i'$-band filter (*19*). These measurements (*20*) shown in the Fig. 6 graph, which plot the Table 2 [$i'$ (mag)] column ("imag") versus the [$z_{\text{phot}}$] column ("z") in Ryan *et al.*, appear as the small violet dots at higher magnitudes (i.e., dimmer) than the SDSS data in red.

The identical predictive curves seen in Fig. 3 and Fig. 4 appear in this graph, although they have now been extended to a redshift of $z = 7$.

This composite of both SDSS and HUDF $i'$-band datasets provides an accurate set of empirical measurements across the complete range of cosmological redshift, from the superclusters local to the Milky Way at $z = 0.02$ to the farthest reaches of the observable universe at $z \sim 7$. In Fig. 6, there is no correlation between the standard model curves in blue and the empirical data, yet the MdR model curve in black is remarkably consistent with both the low-redshift (red) and the high-redshift (violet) observations. Where there is similarly plentiful accurately measured astrophysical data, MdR model predictions match other empirical observables related to cosmology with similar precision as that exhibited for the SDSS and HUDF redshift-magnitude observations (*5*).

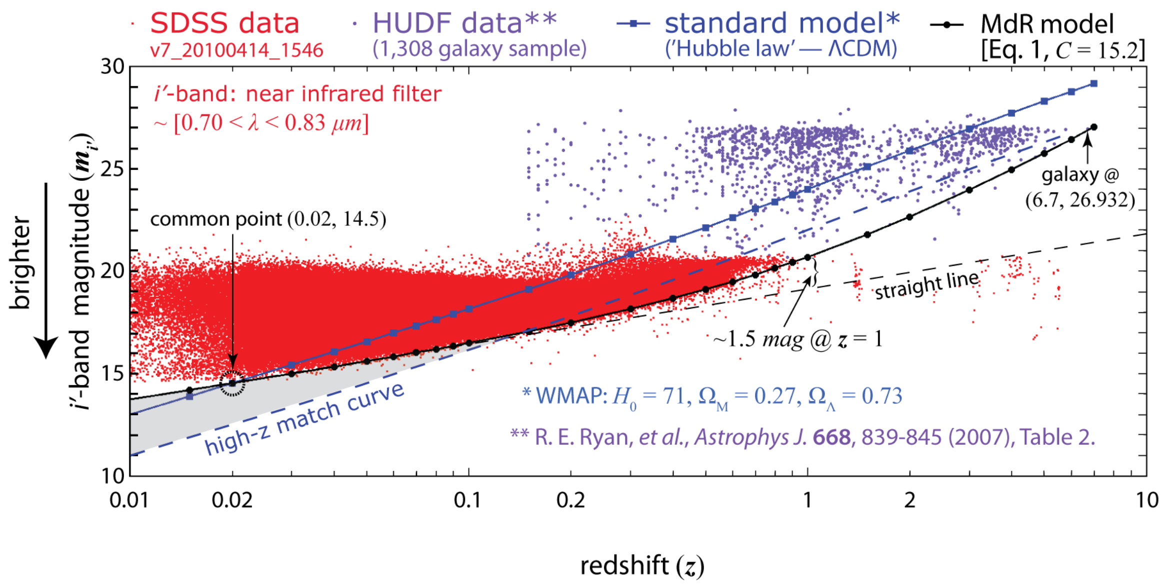


**Fig. 6.** Both SDSS (red) and HUDF (violet) $i'$-band data compared to the same model curves shown in Fig. 3 and Fig. 4, which are extended out to high redshift. The dashed "high-$z$ match curve" in blue shifts the solid curve down to match the high-redshift empirical data. If this curve were an accurate model, galaxies would generally not fall below the curve, but many do ($z > 0.15$), and galaxies would completely fill the gray shaded region shown in the graph, yet no such galaxies exist empirically. The fit of both of these empirical datasets to the MdR predictive curve, which was not known when the datasets were produced, is indicative of the remarkable quality of the observational data. Note the highest redshift galaxy in the HUDF dataset; what must be among the brightest class of galaxies to be visible at this redshift ($z = 6.7$) falls on the MdR predictive curve.

If the SDSS and HUDF data can show the demonstrated measurement accuracy, then all previously published empirical redshift-magnitude curves and error bars, which supported the 'Hubble law' and the Big Bang paradigm by expectation, require retraction and correction. Given the scientific facts revealed in this article, if SNe Ia are indeed reliable standard candles, raw preprocessed SNe Ia luminosity measurements should clearly follow the redshift-magnitude curve defined by Eq. 1.

In the effort to measure $q$, the important discovery of an increasing trend in the slope of the SNe Ia redshift-magnitude curve was correct, but the reported average slope for the supernovae is inconsistent with statistically and procedurally far more reliable SDSS empirical data. An accurately reported empirical redshift-magnitude curve as shown in Fig. 6 changes the interpretation of the observed slope increase with redshift while dispensing with the dubious concept of 'dark energy' and overthrows the standard cosmological model (i.e., the Big Bang theory). It also dispenses with the notion that distant galaxies are receding from the Milky Way Galaxy at speeds greatly exceeding the speed of light, which was one of several acts of handwaving needed to maintain the quasi-religious idea of a single cosmic "moment of creation" followed by expansion.

Although the cosmic microwave background (CMB) radiation and the more recently reported measurements of its anisotropy have been touted as proof of the Big Bang theory, if the 'Hubble law' does not hold and therefore the Universe is not expanding, the CMB requires a new explanation to replace the conventional belief that it represents leftover heat from a primordial explosion assumed to have occurred about 13.7 billion years ago. This has been addressed in the referenced dissertation, including readily observable empirical predictions (*5*).

The MdR theory introduced herein is based on an amendment to the treatment of time in the theory of relativity. A number of important corrections to 20$^{th}$-century theoretical physics arise from this amendment, in addition to those in the field of cosmology (*5*). Kathryn Schulz's new book, *Being Wrong: Adventures in the Margin of Error* (2010), is highly recommended scholarly reading that may assist individuals in understanding and coping with the contemporary sea change in theoretical physics and cosmology.


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2. S. Perlmutter *et al. Astrophys. J.* Measurements of Omega and Lambda from 42 High-Redshift Supernovae, **517**, 565-586 (1999).

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4. U. Sawangwit, T. Shanks, ΛCDM and the WMAP power spectrum beam profile sensitivity, Proceedings of the conference "45$^{th}$ Rencontres de Moriond" – Cosmology Session, La Thuile, Val d'Aosta, Italy, March 13–20, 2010 (available at http://arxiv.org/abs/1006.1270v1).

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7. The 2dF Galaxy Redshift Survey (available at http://magnum.anu.edu.au/~TDFgg/).

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12. SDSS, *Fiber magnitudes* (2004),
(available at http://www.sdss.org/dr7/algorithms/photometry.html#mag_fiber).

13. SDSS, Target Selection: Quality and Efficiency, The main galaxy sample, (2004),
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14. S. Perlmutter, *Philos. Trans. R. Soc. London Ser. A*, Dark energy: recent observations and future prosepects, **361**, 2469-2478 (2003).

15. SDSS, *Luminous Red Galaxies* (2007),
(available at http://www.sdss.org/dr7/algorithms/target.html#lrg).

16. A. Pais, *Subtle is the Lord… The Science and the Life of Albert Einstein*,
(Oxford University Press, Oxford, 1982), p. 152.

17. Pogson's equation may be written [ $m = k - \sqrt[5]{100}\,\log_{10} B$ ] where $B$ is apparent brightness and $k$ is some constant. Given the approximation $\sqrt[5]{100} \approx 2.512$ (Pogson's ratio), then $2.512^{\Delta m}$ is the factor by which apparent brightness changes for a change in magnitude of $\Delta m$.

18. S. V. W. Beckwith *et al. Astron. J.* The Hubble Ultra Deep Field, **132**, 1729-1755 (2006).

19. R. E. Ryan *et al. Astrophys. J.* The Galaxy Luminosity Function at $z \simeq 1$ in the HUDF: Probing the Dwarf Population, **668**, 839-845 (2007).

20. Data in electronic form available at http://jaypritzker.org/J/1/Ryan (redirects to iop.org).



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**Supporting Online Material**

Materials and Methods
Figs. S1, S2, S3, S4

**See http://jaypritzker.org/J/1/HowTo (be transferred to journal website).**

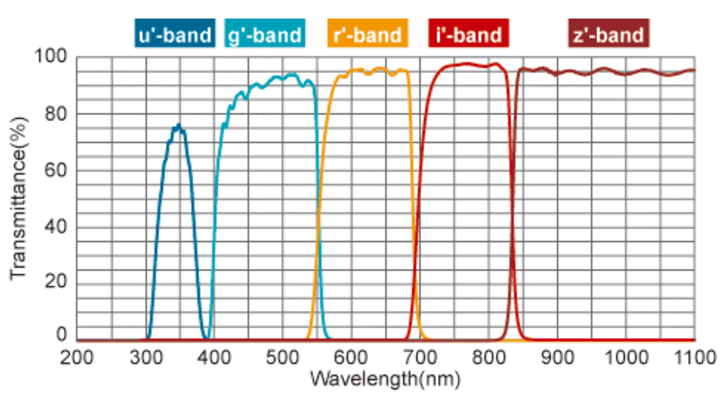


**Fig. S1.** SDSS bandpass filter characteristics (ASAHI Spectra USA).

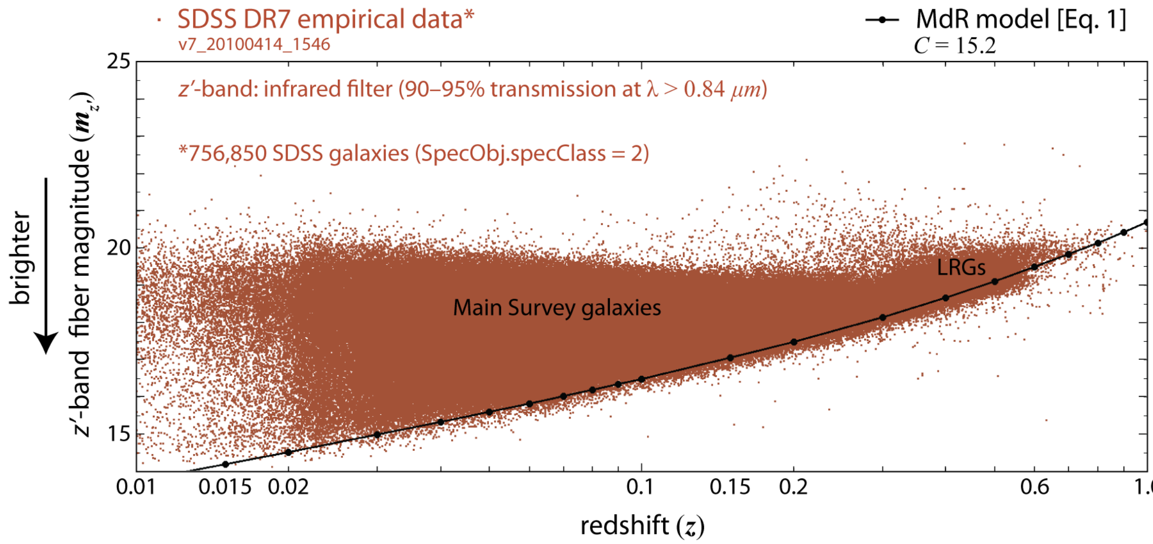


**Fig. S2.** SDSS $z'$-band (infrared) data compared to MdR model curve. The tendency of longer-wavelength IR photons to better penetrate the IGM dust is more pronounced for the $g'$-band data than for the $i'$-band data. Thus, the $g'$-band data is slightly brighter overall than the $i'$-band data and the relative brightening of the base of the dataset relative to the zero extinction MdR model with increasing redshift is slightly amplified.

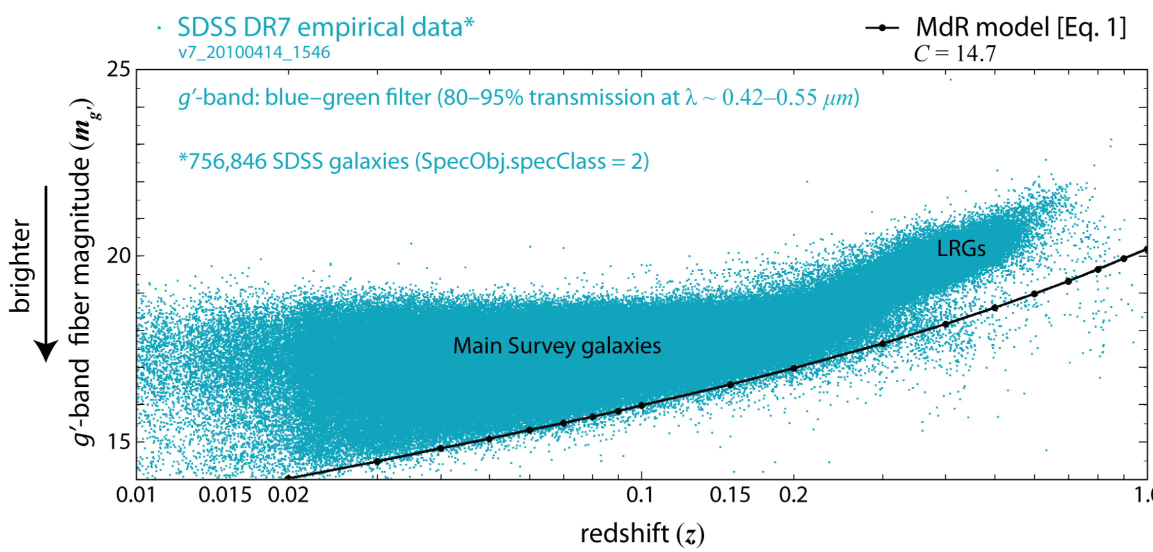


**Fig. S3.** SDSS $g'$-band (blue-green light) data compared to MdR model curve. Local dust surrounding the LRGs has a greater extinction effect on light of this shorter wavelength than for the $r'$-band. As expected according to basic theory, progression of the extinction effect with decreasing wavelength beginning with the infrared $z'$-band data is evident. Comparative analysis of the data provides empirical measurement of the relative abundance and size of dust grains surrounding dusty (i.e., red) galaxies.

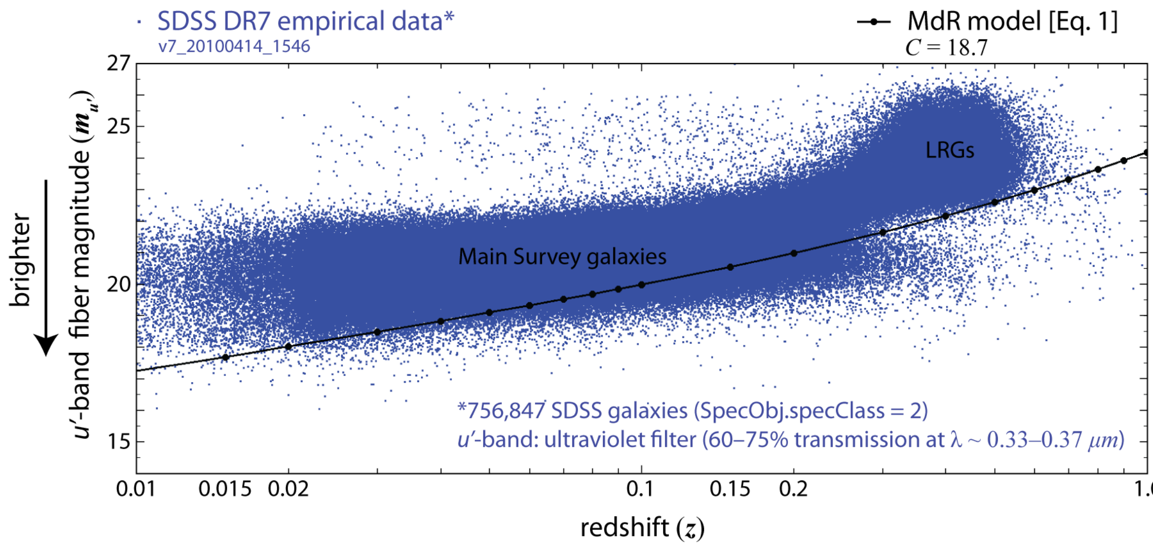


**Fig. S4.** SDSS *u′*-band (ultraviolet) data compared to MdR model curve. This graph, and in particular the LRG region, contrasts sharply with the graphs for the other four SDSS bands, which all share similar characteristics. The cause for this difference is unclear and requires explanation. Although the *u′*-band filter has a far narrower frequency range than the other four filters (Fig. S1), this does not explain the observed flatness of the base of the dataset and the increased range of LRG luminosities at this wavelength as compared to the four longer wavelengths. It would appear that an algorithm was applied to *u′*-band magnitudes for the specific purpose of expanding the luminosity range of the LRG population from an empirical value of less than 2 *mag* as seen for all of the other four wavelengths, to about 4 *mag* in the ultraviolet. Perhaps this was done to meet some preconceived theoretical expectation for the LRG population. This would explain the apparent artificial brightening of the brightest high-redshift galaxies in the Main Survey relative to their low-redshift counterparts. Although this anomalous and possibly false redshift-magnitude data limited to the ultraviolet band is not referenced in the body of this article, it has been included here for completeness.